Visible/Near-IR vs. Uncooled Long Wave Infrared Automatic Target Recognition

Lower Cost of ATR/Fusion by 100 Times
Extend Range Non Conventional Targets
(for Collaborative Technology Alliance - Army Research Lab & IR&D)

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First ATR Flight Trials

	1970s	1980s	1990s	2000s
FLIR				
SAR				
Fusion				
Visible*				

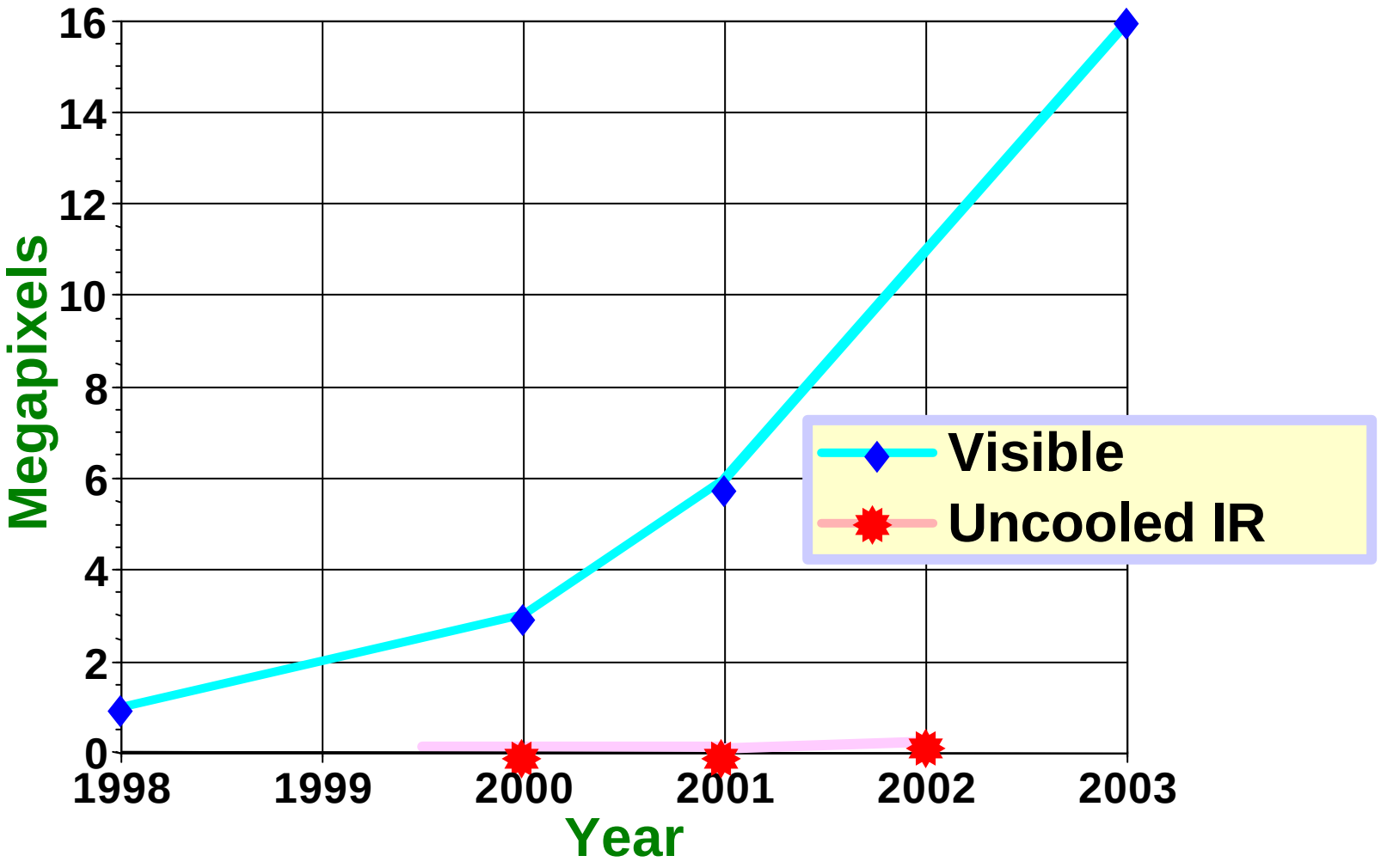
* 6.1 Exploratory Research

Vis-NIR vs. Uncooled FLIR ATR

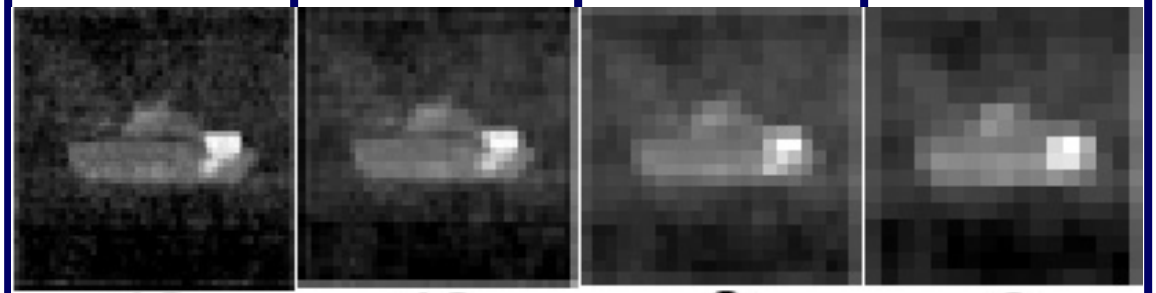
- **Case for Vis-NIR**
  - Sensor Cost: VIS-NIR=0.02¢/pixel vs. Uncooled FLIR=40¢/pixel
  - Commercial base: HDTV, camcorders, digital cameras, JPEG, MPEG, etc.
  - Military vehicles have 4 times reflectivity in NIR as compared to visible
  - FLIR does not work well at mid-day

- **Case for Uncooled FLIR (long wave infrared)**
  - Military vehicles are painted to defeat recognition in visible (but not NIR!)
  - Cost may be high, but still much less than cooled 2nd gen FLIR
  - Active targets “pop-out” at night
  - Long wave IR not affected by solar reflections
  - Cleaner psd function than 2nd gen FLIR systems

Small Cameras (~1lb)



Small FLIR
15º VFOV, 120 lines
(Unmanned Ground Station scenario)

Lines on Target	 18	12	8	6
Range to Target	51 meters	77 meters	116 meters	154 meters

Data Collections

Vis/NIR vs. Uncooled FLIR

5 in 2001
3 planned for 2002
air-to-ground, ground-to-ground
short range (UGS, small UAV) (<1 km)
long range (> 1km)

Visible & Near-IR

Kodak 620x, 720x

Nikon D1, D1x, etc.

3rd gen intensifier

Uncooled FLIR

FLIR Sys. PM695

Mikron 7200

Indigo Omega

(not tested yet)

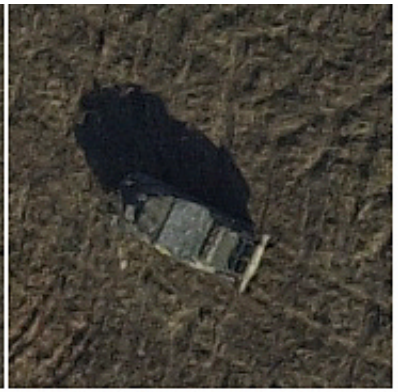
Illuminators

Xenonics NightHunter

Gilway

GE

ZSU23/24



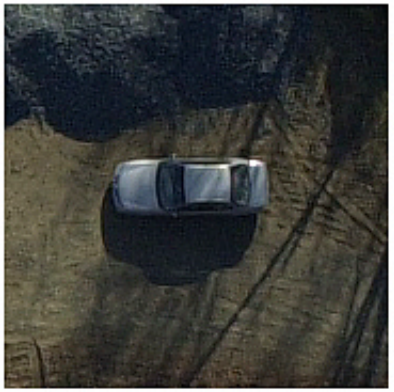
BRDM2

BTR70

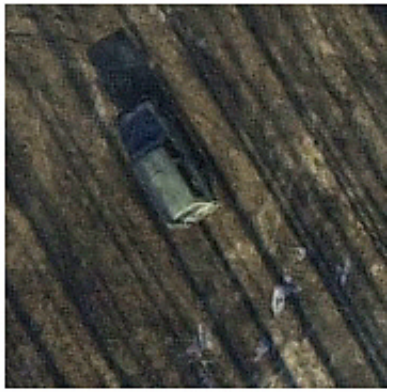
BMP2

BMP Decoy

M1078 FMTV



Chevy Malibu



CUTV

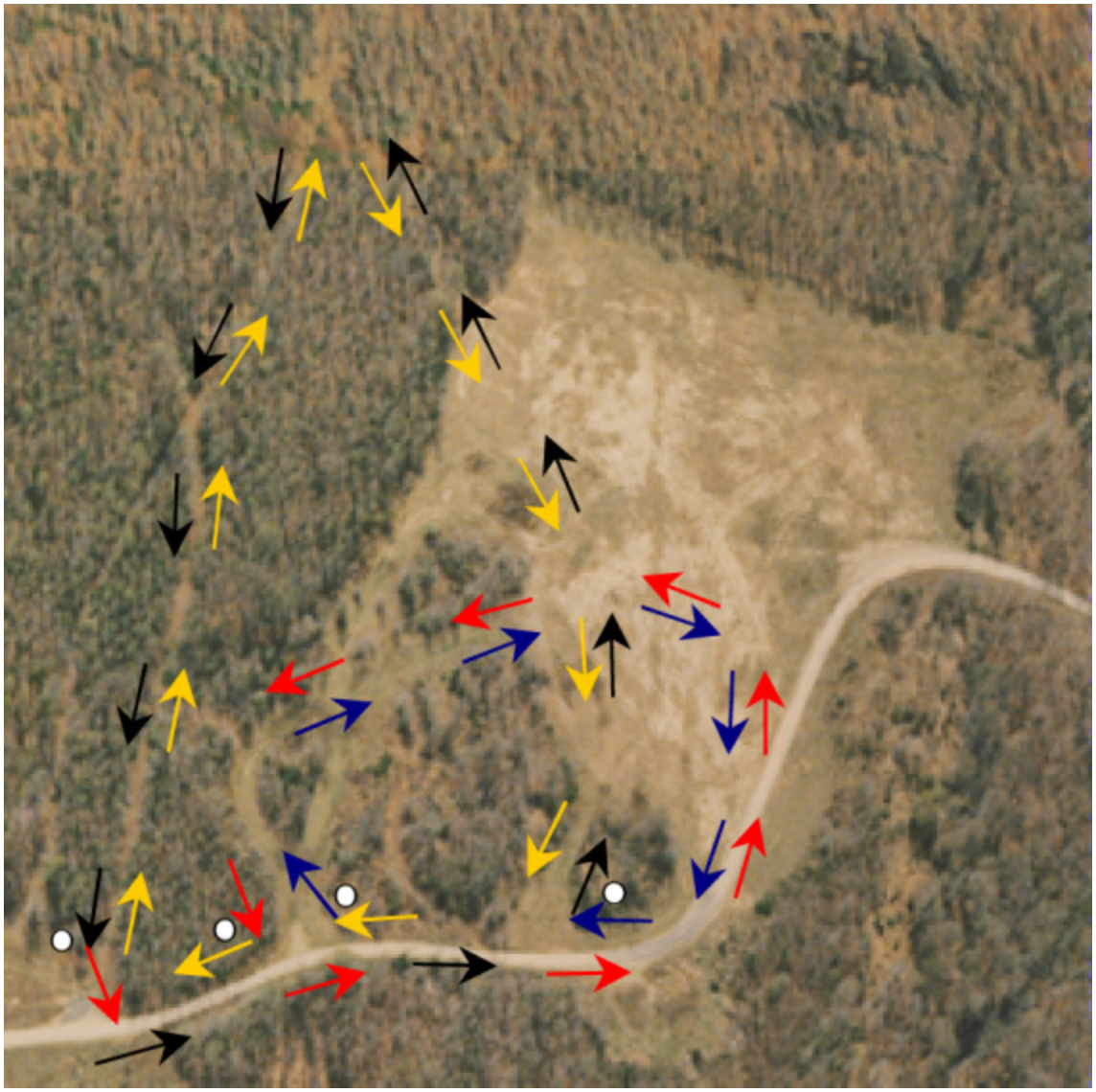
2S1

T72

Case 850 Dozer

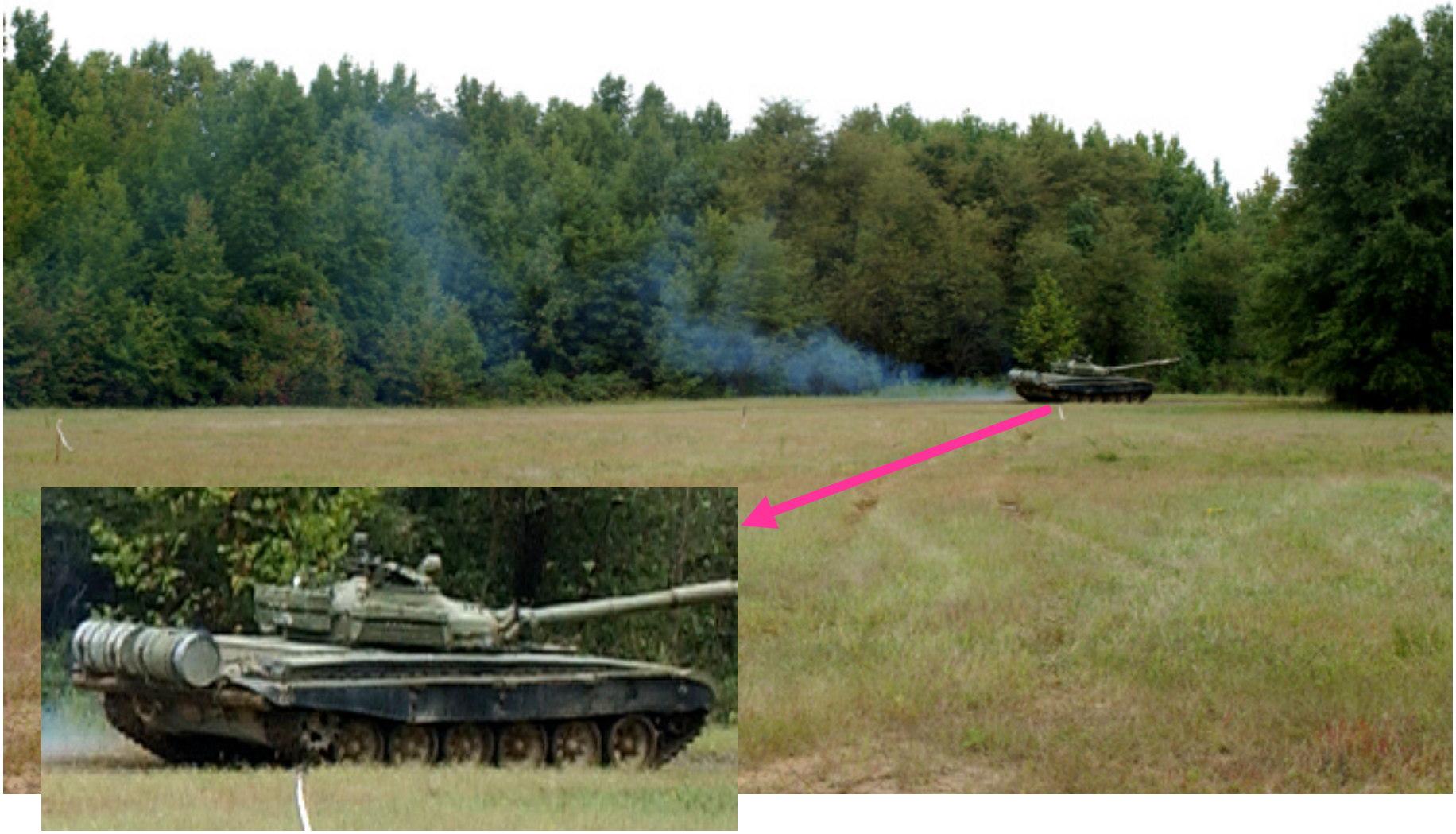
M548A3

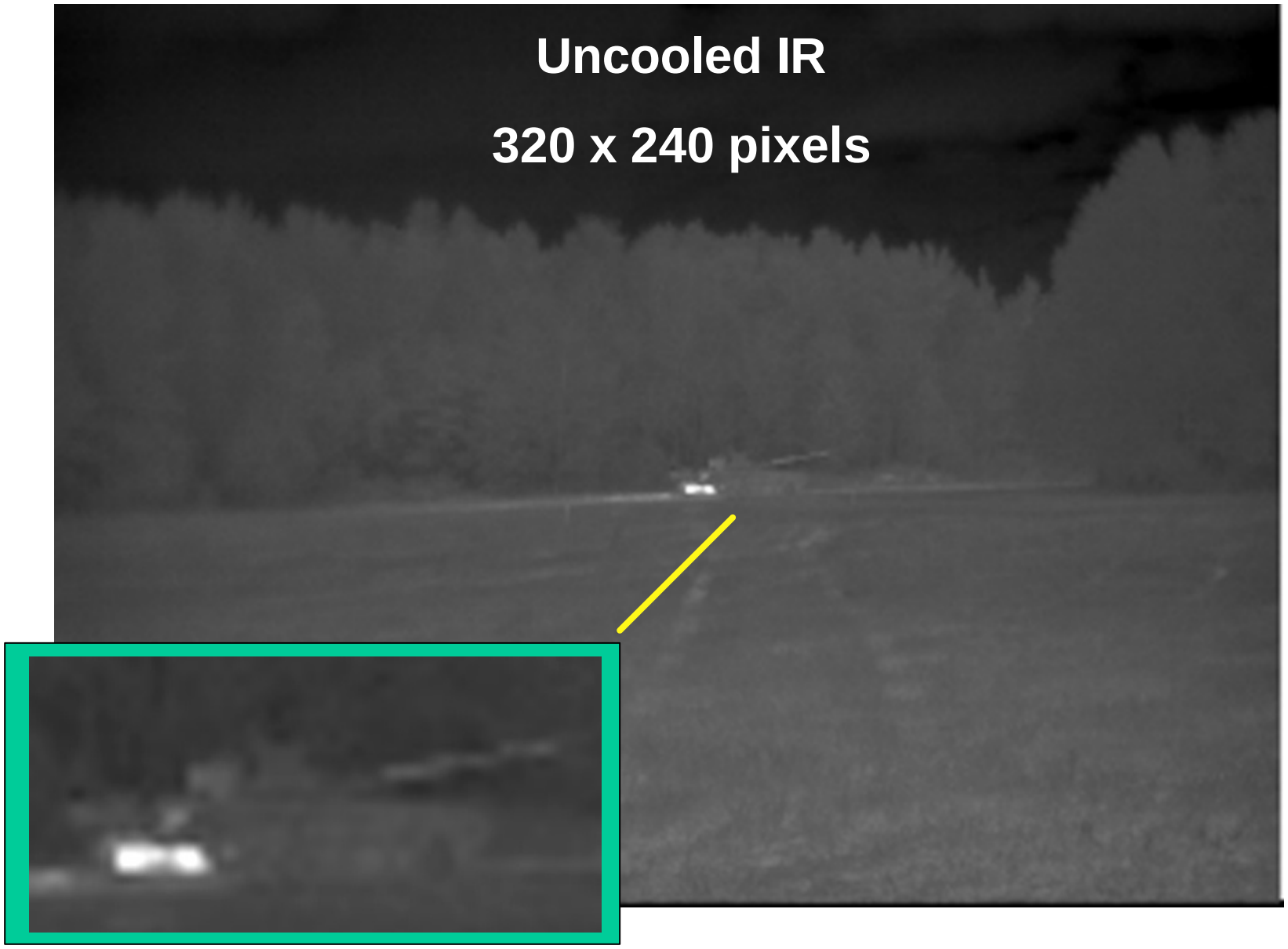
Scenario B



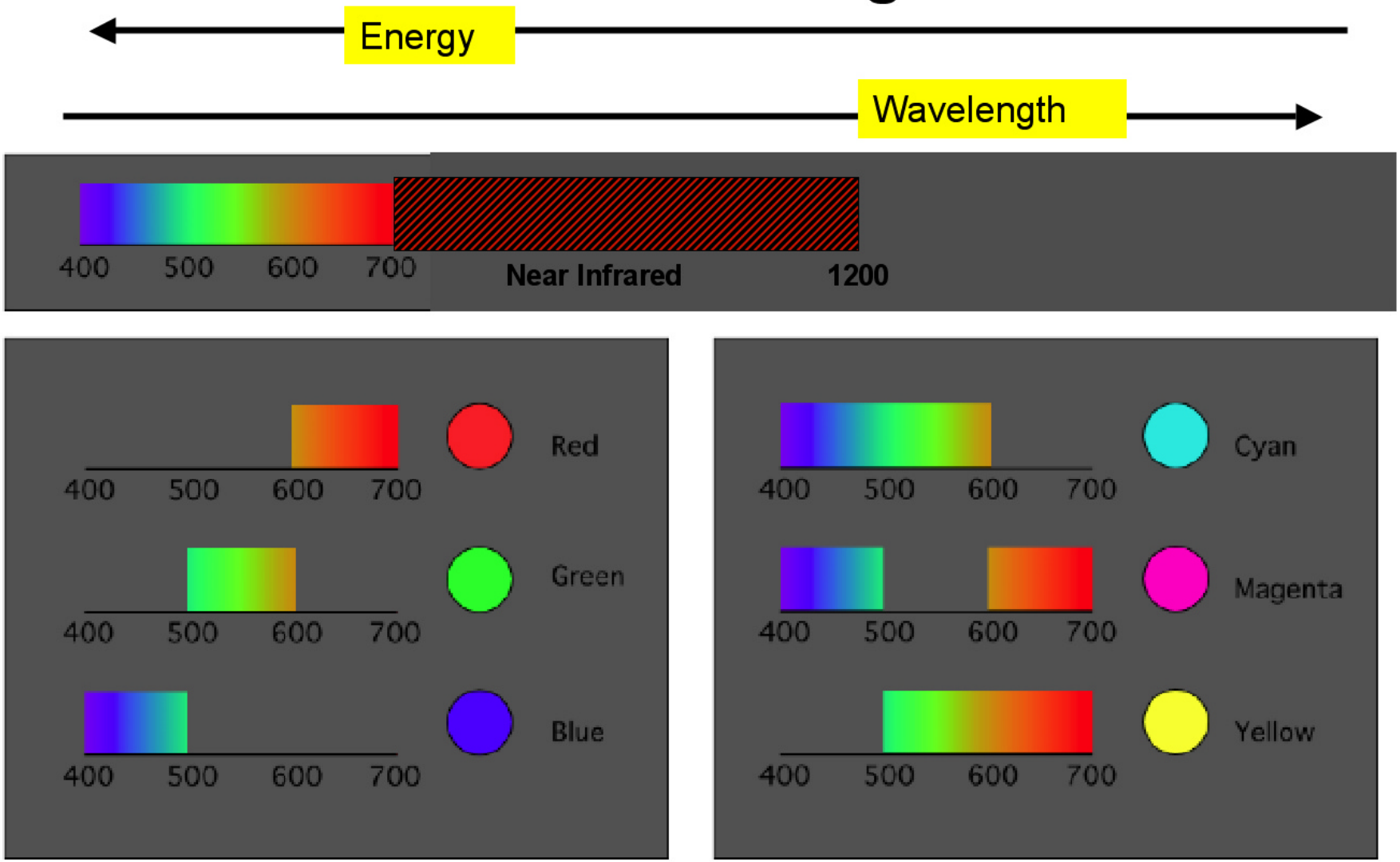
3008 x 1960 pixels

Nikon D1x



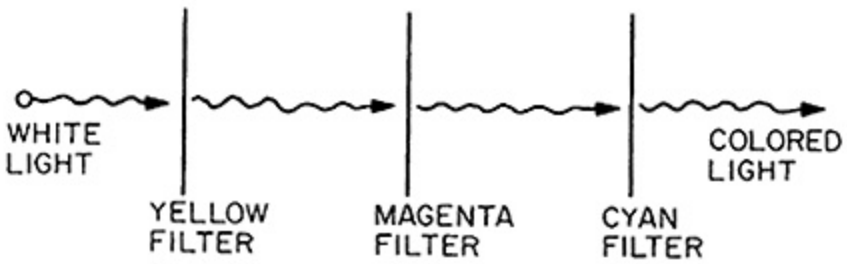

Uncooled IR
320 x 240 pixels

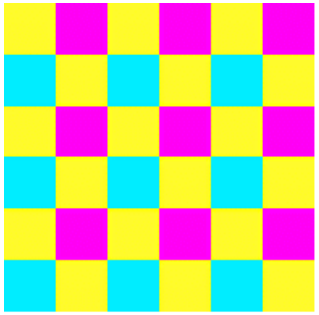
What Bands are Best for Target Detection and Recognition?



{Red, Green, Blue} vs. {Cyan, Magenta, Yellow}

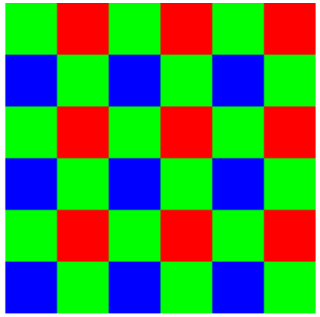
White light is passed through cyan, magenta, and yellow filters.





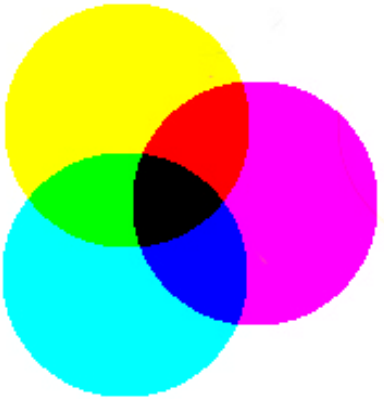
CMY Bayer Pattern

Kodak 720x



RGB Bayer Pattern

Nikon D1



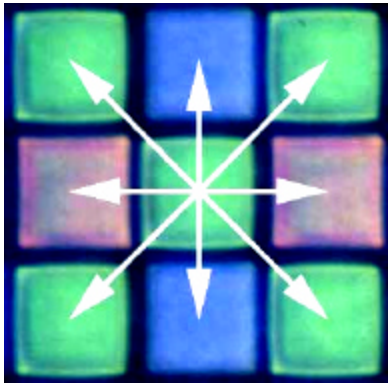
Red = Yellow + Magenta

Green = Yellow + Cyan

Blue = Magenta + Cyan

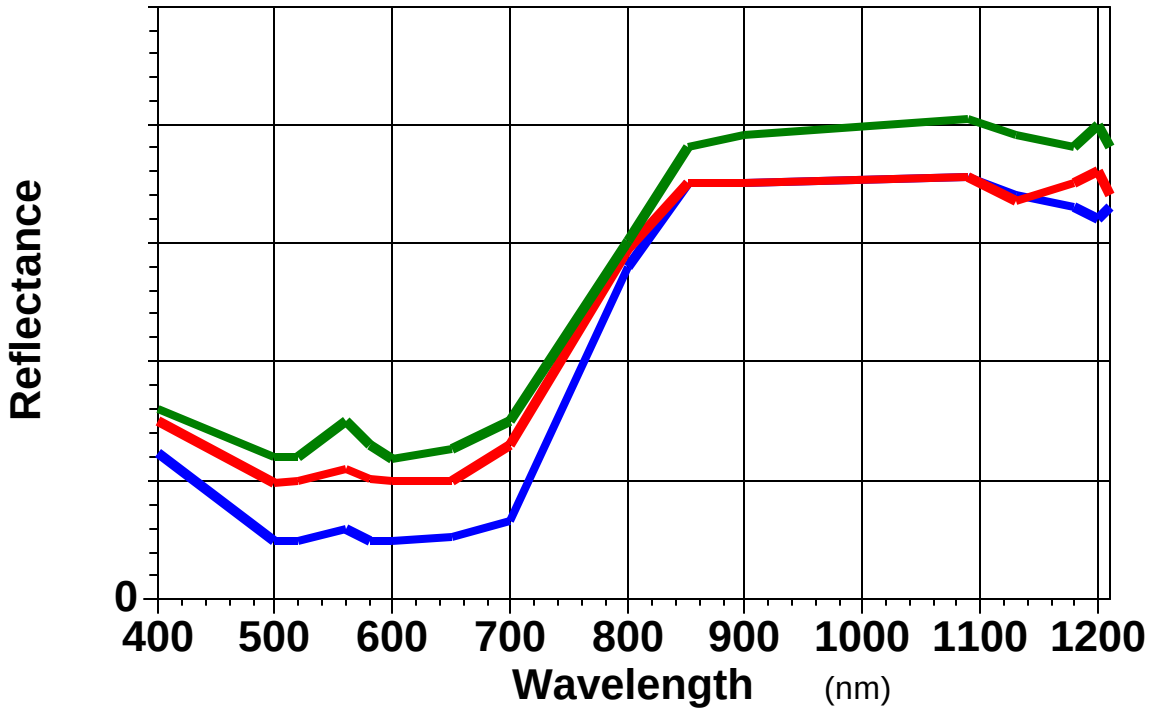
Vector Pixels

(Green = low noise)



Importance of Near IR Component

Vis-NIR Spectral Response of 3 Samples of Green CARC Paint



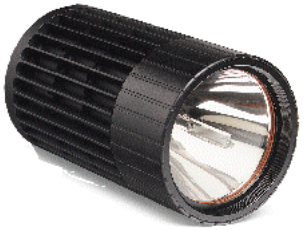
From: “Surface Reflectance Variations of Realistic Targets”, D. Thomas, R. Evans, J. Crosby, TACOM

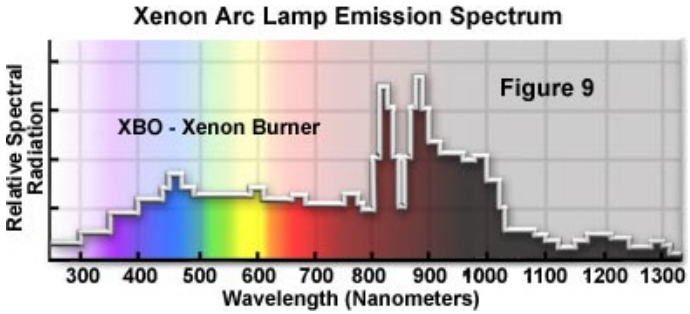
Vis/NIR Band Choices

- Magenta
- Yellow
- Near infrared (or visible + near IR)

Active Near IR Illumination

Xenon





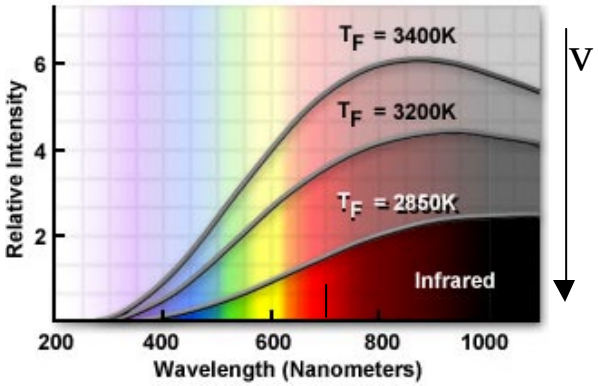
Xenonics Illuminator:
Tested 75watt, 10º beam, at 200 meters, 1/30 sec.
Note beam goes to 1º.

Guide 200 flash attachment

-> 200 ft range for ISO 100
Or >1 km at ISO 25000

Halogen

MR-16



4, 8, 10, or 12 degree beam

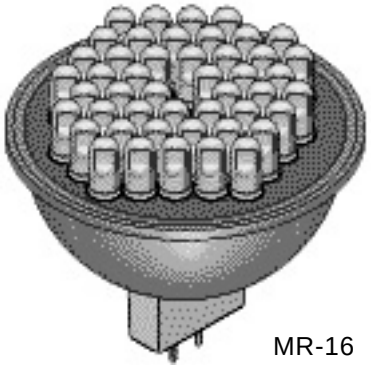
Aluminum reflector (non dichroic)

12v, 50-100 watt

14,000 candela vis. (65w, 10º, $9);

65,000 candela (4º)

IR LED Array



MR-16

850, 880, or 950 nm

12 degree beam

12 volt, 4 watts

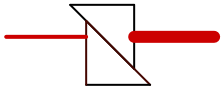
equiv. 200 candela

$120

What's New

Laser Spot

1500 nm

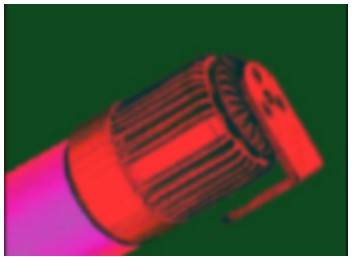


~0.5°

4.3m high at 500m

Halogen with Gold Reflector

Highest IR Reflectivity

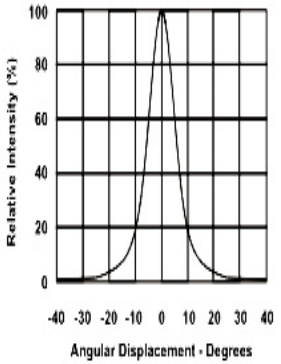


~2°, 100 watt ==> Range > .5km

~ 500,000 candela

Luxeon Star LED

Highest in-band illumination per watt



825 candela on axis

Approaches to Target Detection

Leopard in Tree

camouflage

Snow Rabbit

- **Anomaly Detection** (for SAR & long wave IR - but not **visible**)
- **Change Detection** (for moving targets)
- **Pattern Detection** (Gestalt ={scale, shape, edges & texture})

Target Detection (single frame)
IR vs. Visible (UGS Day Scenario)

Visible

Target Not Detected

Uncooled Long Wave IR

Very Strong Detection

Magenta, Yellow, NIR

Strong Detection

Much

Rarer

Case

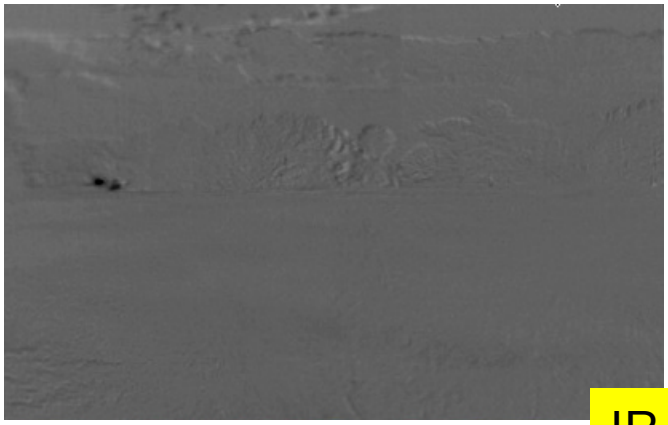
Visible

Very Strong Detection

Uncooled Long Wave IR

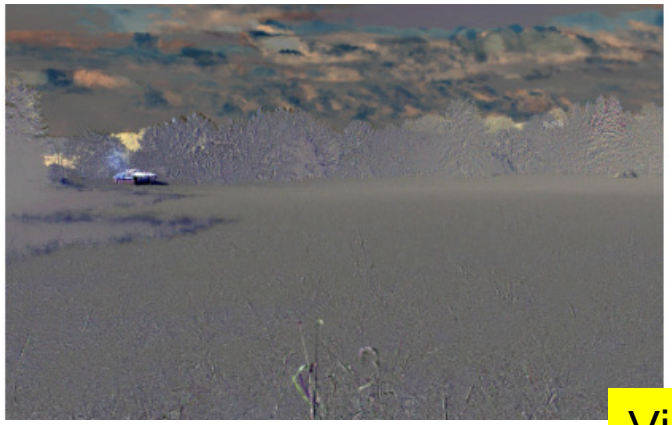
Target Not Detected

Moving Target Detection
Simple 2-Frame Change Detection



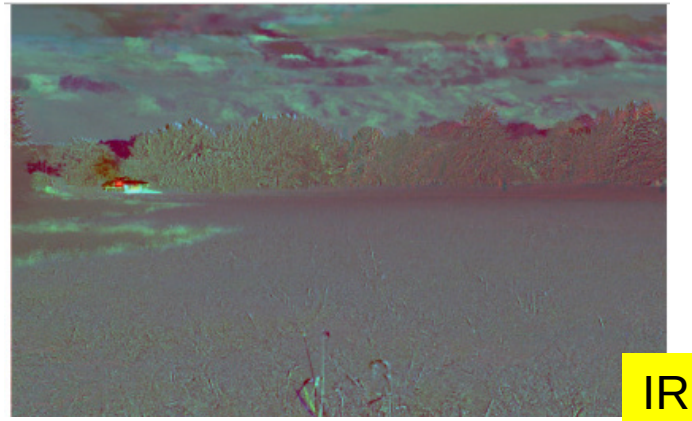
IR

Detection



Visible

No Detection



IR, Green, Blue

Simple Multi-frame Change Detection

Fifth image of moving BTR-70.

Moving target detection image Δ.

Equation

$$\Delta = |t_i - t_{i-1}| + |t_i - t_{i-2}| + |t_i - t_{i-3}|$$
$$+ |t_i - t_{i-4}| - |t_{i-2} - t_{i-4}| - |t_{i-1} - t_{i-3}|$$

Target at full resolution

D *image*

Approaches to Fusion (Visible + FLIR)

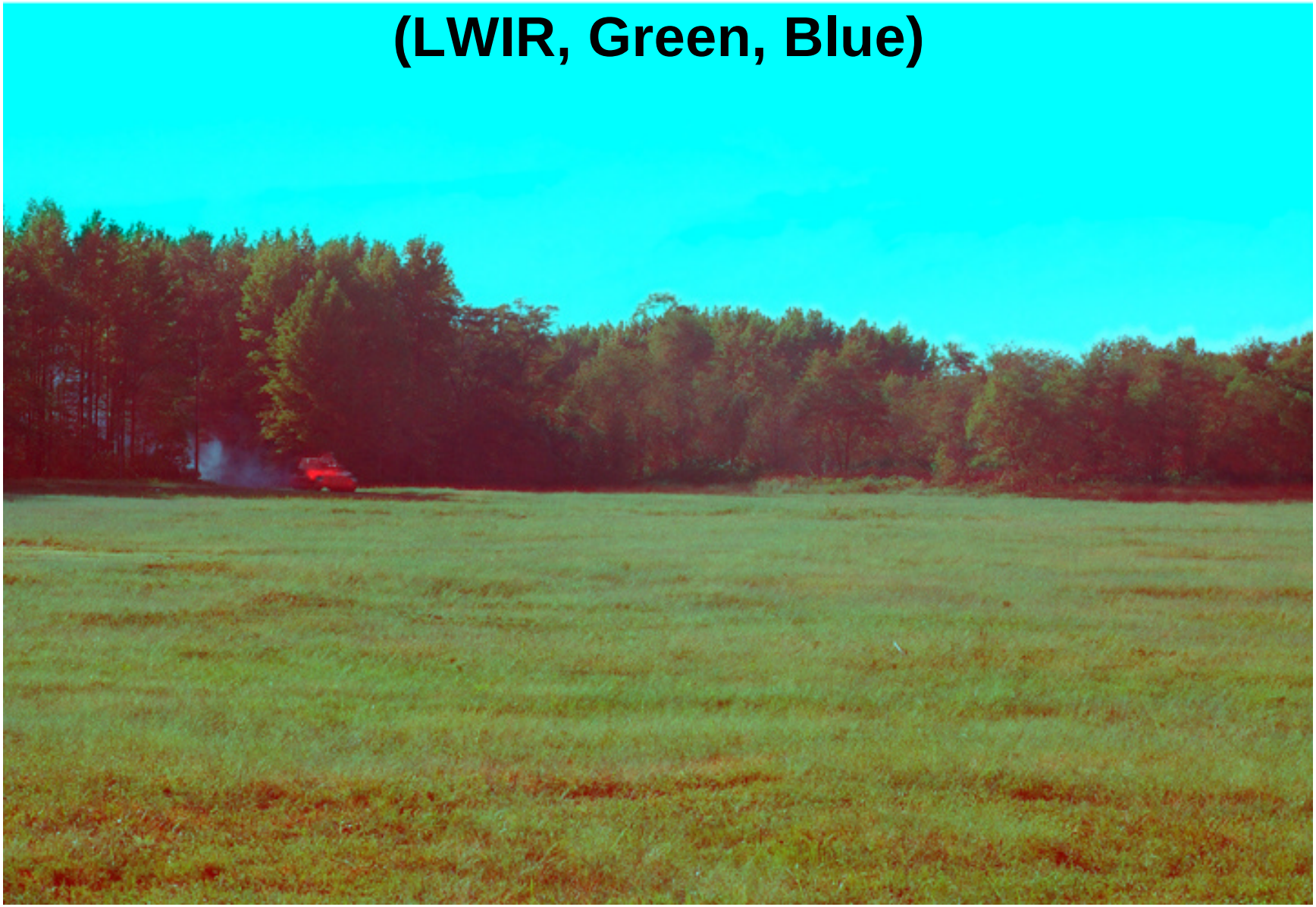
- Pixel Level fusion ==> multi-band
- Feature Level fusion
- Post declaration fusion
- Plug in sensor based on conditions

- Single sensor multi-look fusion

- trade temporal for spatial bandwidth

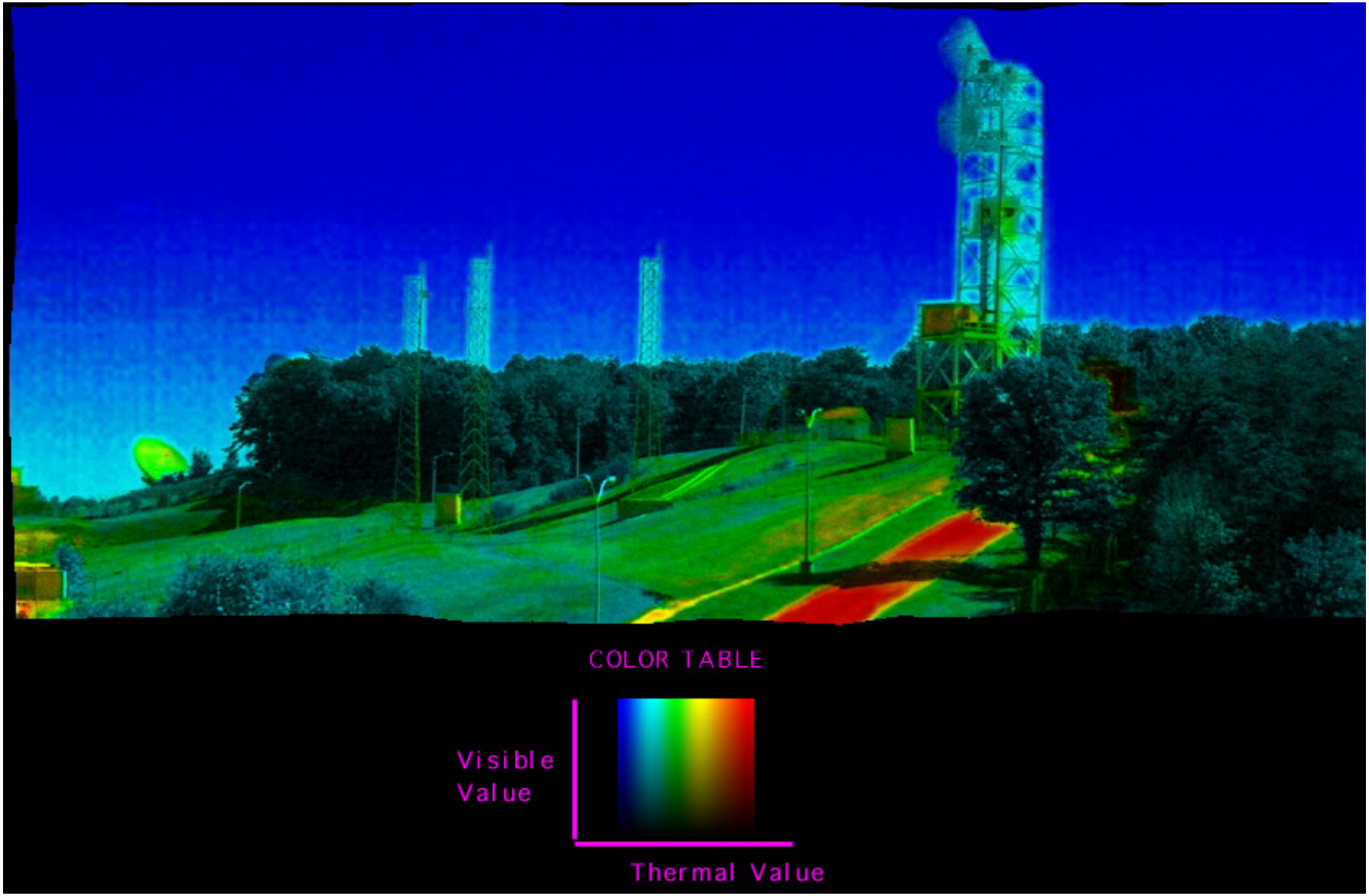
Fusion of Visible and Uncooled FLIR (LWIR, Green, Blue)

Fusion of Visible and Uncooled FLIR (LWIR, Green, Blue)

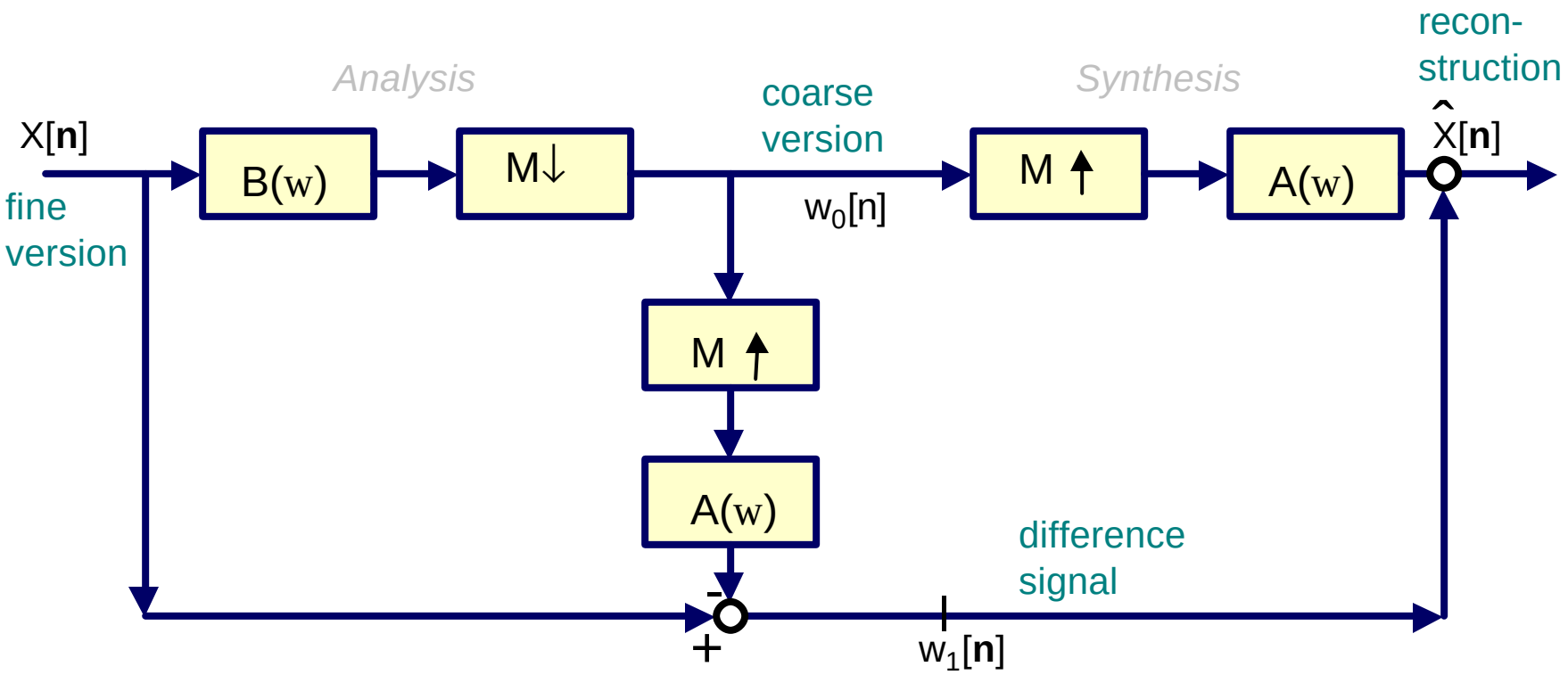


Fusion of Vis and Uncooled FLIR

(Treating each pixel as vector {Vis,LWIR} and mapping to false color)

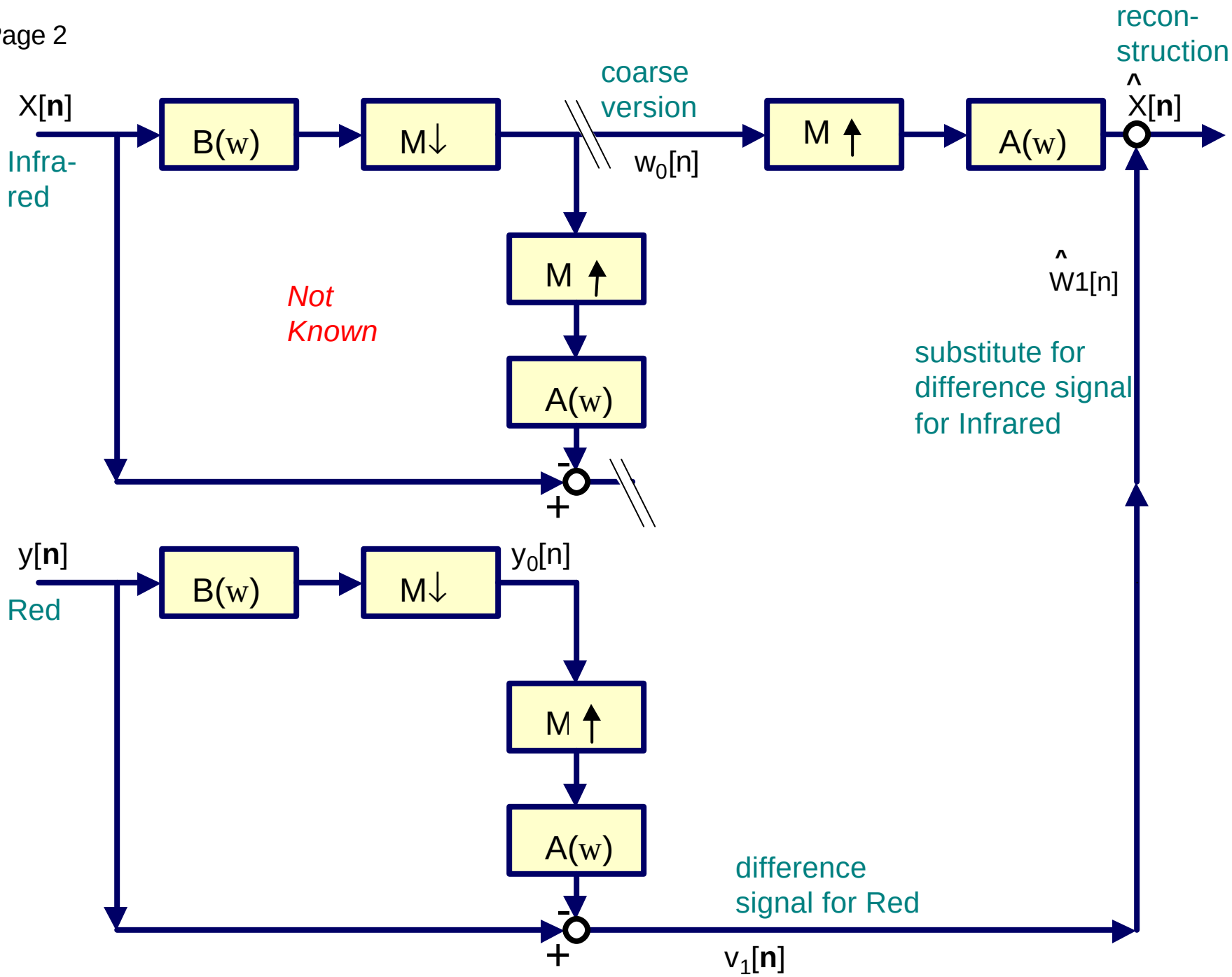


Resolution Enhancement of Microbolometer Data - page 1

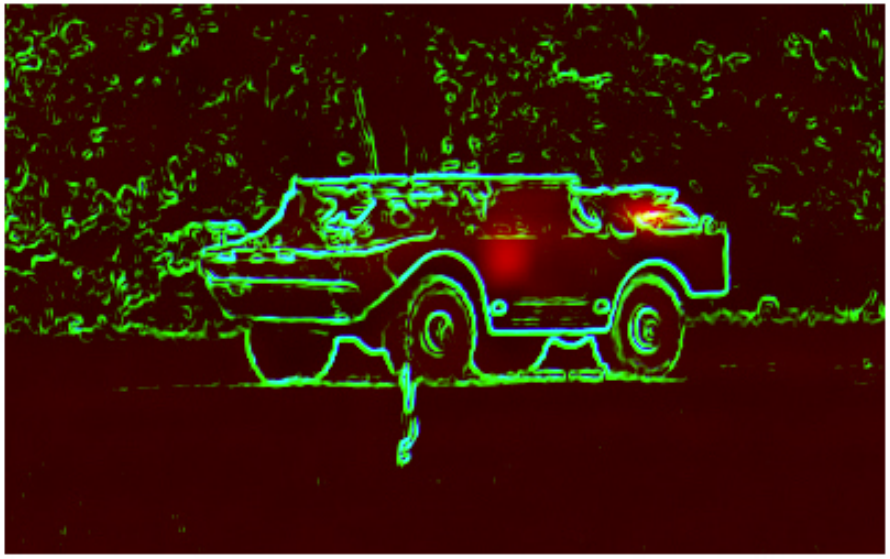


Construction of one level of Laplacian pyramid.

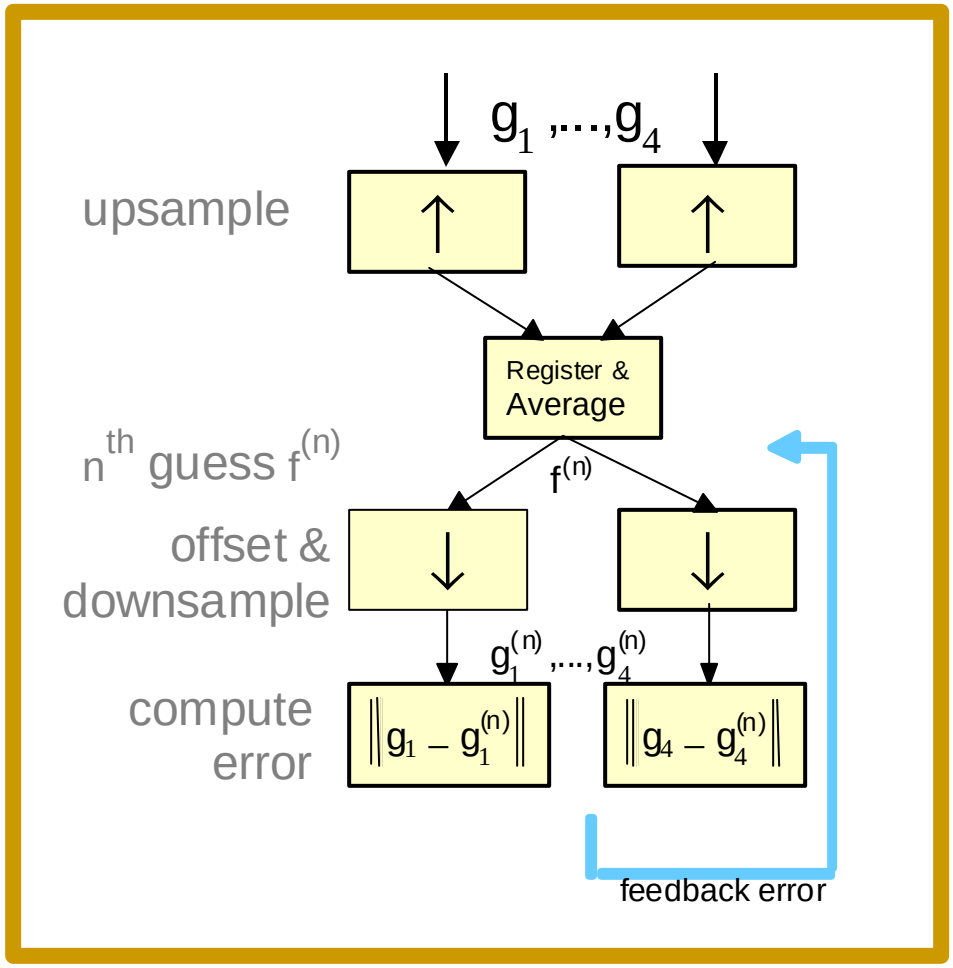
This transformation may also be described as an analysis/synthesis filter bank.

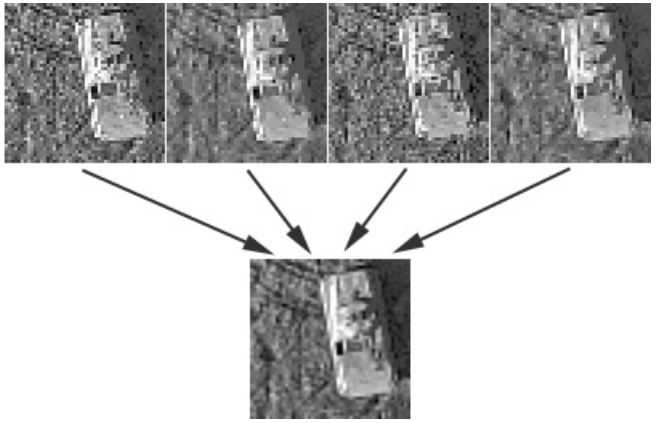

recon-
struction
X[n]
coarse
version
X[n]
Infra-
red
B(w)
M↓
M ↑
A(w)
w0[n]
M ↑
Not
Known
W1[n]
A(w)
substitute for
difference signal
for Infrared
-
+
y[n]
Red
B(w)
M↓
y0[n]
M ↑
A(w)
difference
signal for Red
-
+
v1[n]

Embedding Detail from Ultra-high Resolution Vis-NIR into Uncooled FLIR



Multi-frame Super-Resolution of Uncooled FLIR Data





Vis/NIR vs. Uncooled Long Wave IR - Early Conclusions

- Conclusions do not hold under all conditions
- And are not backed by government blind tests as with other sensors

- {Magenta, Yellow, Near IR} better for ATR than {Red, Green, Blue}
- Simple anomaly detection works better in LWIR than Visible bands
- Simple change detection works better in LWIR than Visible bands
- But, targets can be detected in Vis/NIR using pattern and change analysis.
- Uncooled LWIR is particularly good for detection, but doesn’t supply detail for recognition beyond moderate range.
- Visible / Near IR can be fused with Uncooled LWIR for little extra cost